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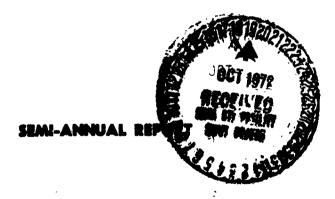


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GENERATION OF LONG TIME CREEP DATA ON REFRACTORY ALLOYS AT ELEVATED TEMPERATURES



NATIONAL APPONAUTICS AND SPACE ADMINISTRATION LEWIS RESEARCH CENTER **UNDER CONTRACT NAS 3-15554**

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SEMI-ANNUAL REPORT
CONTRACT NAS-3-15554

8 May 1971 to 8 November 1971

GENERATION OF LONG TIME CREEP DATA ON REFRACTORY ALLOYS AT ELEVATED TEMPERATURES

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FOREWORD

The work described herein is being performed by TRW Inc. under the sponsorship of the National Aeronautics and Space Administration under Contract NAS-3-15554. This contract involves work similar to that conducted under Contracts NAS-3-13469, NAS-3-9439, and NAS-3-2545. The purpose of this study is to obtain design creep data on refractory metal alloys for use in advanced space power systems. A listing of all reports presented to date on this program is included in Appendix 1.

The program is administered for TRW Inc. by H. E. Collins, Program Manager; K. D. Sheffler is the Principal Investigator with R. R. Ebert supervising the experimental program. The NASA Technical Manager is Paul E. Moorhead.

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ABSTRACT

Ultrahigh vacuum creep tests have been conducted on tantalum, tungsten, and molybdenum alloys to develop creep data and to evaluate the influence of liquid lithium exposure on the creep behavior of the tantalum alloy T-111. Test conditions were generally selected to provide 1% creep in 1000 to 10,000 hours, with test temperatures ranging from 1600 to 2912°F (1144 to 1873°K). Tests on T-111 specimens exposed to vacuum and to liqu. 1 lithium for various times and temperatures showed large reductions in creep strength for exposures in the 1800 to 1900°F (1255 to 1310°K) range. Tests on the ASTAR 811C alloy showed a significant influence of grain size on the creep strength of this material, with larger grain size specimens being significantly stronger above the equicohesive temperature of 2000°F (1366°K).

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SUMMARY

Ultrahigh vacuum creep tests have been conducted on the tantalum alloys T-1:1 and ASTAR 811C, on CVD tugnsten, and on the molybdenum alloy TZM. Several significant results have been obtained from these tests, as indicated below.

A study of the influence of long time exposures to 10^{-9} torr vacuum and to liquid lithium on the creep life of T-III alloy has shown that the 1% creep life of this material can be reduced as much as two orders of magnitude by a 5000 hour exposure to lithium in the 1800 to 1900°F (1255 to 1310°K) temperature range. Similar but less drastic effects were found to result from 5000 hour hour exposures to a 10^{-9} torr vacuum at the same temperatures. Five thousand hour exposures conducted at 2400°F (1589°K) appeared to have only a minor influence on the creep life of the T-III alloy. No explanation is presently available for this behavior.

Creep life of ASTAR 811C alloy has been shown to be dependent on heat treatment at test temperatures above the equicohesive temperature of 2000°F (1255°K) with a 1/2 hour anneal at 3600°F (2255°K) providing significantly longer creep lives than a 1 hour anneal at 3000°F (1922°K). At test temperatures below the equicohesive temperature the two heat treatments produce comparable creep life. An additional test conducted on ASTAR 811C annealed 100 hours at 3000°F (1922°K) showed a creep life comparable to that produced by the 3600°F (2255°K) anneal, tending to confirm the hypothesis that the dependence of creep life on heat treatment in the ASTAR 811C alloy is basically a grain size effect.

Comparison of creep data generated on CVD tungsten at TRW and at Oak Ridge National Laboratory have revealed a possible creep instability in this material which requires further study.

In a continuation of a previous study, the influence of both composition and processing on the creep life of the molybdenum base alloy TZM was examined. A specially processed disc having a higher than normal carbon content and forged at higher than normal temperatures was found to have greater creep life than a conventionally forged TZM disc.

INTRODUCTION

Creep life represents a major structural property which must be adequately characterized for the successful design of space electric power systems. The purpose of this program is to study the creep behavior of several refractory alloys which are currently being considered as component materials in space electric power systems at the NASA Lewis Research Center.

Because of the uniquely hostile service environment in which space power system hardware must operate, a number of different factors must be considered in evaluating the performance capabilities of candidate materials. One of the most important factors is the operating environment, which will be either the vacuum of outer space or a metallic fluid in which the concentration of reactive gasses is extremely low. Because of the sensitivity of refractory alloys to interstitial contamination, simulation of these service conditions requires that candidate materials be creep tested in a non-contaminating environment such as ultrahigh vacuum. The creep tests on this program are therefore being conducted in ultrahigh vacuum to develop the creep data required for space power system design.

In addition to the design tests which are being conducted, a major effort is in progress to study the influence of liquid lithium exposure on the subsequent creep behavior of T-lil alloy. This problem is an important consideration in space power system design because of the potential operation of the T-lil alloy in contact with the liquid metal in nuclear power systems. The program is a cooperative effort with NASA procuring and heat treating the test specimens; G.E. Evendale performing the liquid metal exposures; and TRW conducting the UHV creep testing.

EXPERIMENTAL DETAILS

Materials

The materials which are currently being tested are TZM, T-111, ASTAR 811C, and CVD tungsten. Processing details and sources of each of the test materials have been summarized previously (1). Chemical analyses of each heat of test material are shown in Table 1.

Only one specimen of TZM alloy is currently on test. This specimen was taken from a specially fabricated, stress-relieved disc of TZM alloy (Heat KDTZM-1175) which had a higher than normal carbon content and which was forged at very high temperatures (3400°F (2144°K)) in order to provide an improved carbide dispersion (2).

The tantalum alloys are being evaluated predominately in the form of nominal 0.030" sheet, although a few selected tests have been conducted on T-111 alloy in the form of strip or plate. All of the tantalum materials are being evaluated in the fully recrystallized condition. Typical microstructures for these test materials have been presented previously (1). The standard heat treatment for the T-111 alloy is 1 hour at 3000°F (1922°K), while the ASTAR 811C alloy is being studied in two conditions of heat treatment, 1/2 hour at 3600°F (2255°K) and 1 hour at 3000°F (1922°K).

The T-111 test material for the lithium exposure program was fabricated as 0.020" sheet by the Wah Chang Company, Heat No. 650050. The material was procured and the specimens were machined and heat treated at the NASA Lewis Research Center. After machining the specimens were given a duplex heat treatment consisting of a 1 hour at 3000°F (1922°K) followed by 1 hour at 2400°F (1589°K) in a diffusion pumped vacuum chamber. This heat treatment was designed to simulate the standard 3000°F (1922°K) anneal followed by a post-weld stress relief which would normally be applied to any fabricated hardware item. After annealing, different specimens were exposed to lithium or to a 10⁻⁹ torr vacuum for various times and temperatures, as indicated in Table 2. The as-received, post annealed and post exposure oxygen analyses for the 1000 hour specimens are presented in Table 3. These analyses, made at the NASA Lewis Research Center, indicate significant oxygen pick-up during the annealing treatment, followed by a corresponding decrease in oxygen level as a result of both the vacuum and lithium exposures, with the lithium deoxidation being more severe at both exposure temperatures.

The CVD tungsten which is being evaluated on this program was obtained in the form of 4" long by .060" thick sheet-type creep test specimens which were vapor deposited and machined to print by the vendor. Chemical analysis from a typical specimen is presented in Table 1, while a typical photomicrograph appears in Figure 1. The specimens were of the duplex type, meaning that the cross section contained approximately 45 mils of a structure typical of the fluoride deposition process, and approximately 15 mils of a structure typical of the chloride deposition process. The annealing treatment for these specimens was 100 hours at 3272°F (2073°K)

Table 1

		H ₂ Finished Form	9 Forged disc	6 Nominal 0.030" sheet	-	=======================================	= =	= =	=	= = 0.		2.8 Nominal 0.600" plate	1.6 Nominal 0.165" strip	l Nominal 0.020" sheet	0	Nominal 0.030" sneet	3.5	2 Nominal .060" sheet
gram		2	34	55	30	00	20	72	25	30	2]	00	34	33		<u>+</u> -2	. 06	7
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Chemical Composition of Alloys Being Evaluated in Creep Program		Zr	.130															
g EV			.61															
ys Bein		ပ	0.350	4400.	.0030	00400.	.0030	00.00	.0036	.0030	000.	.0025	.0037	.0022	9	0300	.0200	.0029
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		Material	TZM (Heat KDTZM-	T-111 (Heat 70616)	(Heat 65079)	(Heat 65076)	(Heat D-1102)	(Heat D-1670)	(Heat D-1183)	(Heat 650028)	(Heat 848001)	(Heat 650038)	(Heat 8048)	(Heat 650050)	ASTAR 811C	(Heat VAM-95)	(Heat 650056)	CVD Tungsten

Table 2

		T-111 Alkali	i Metal Exposure Program Identification Numbers*	T-111 Alkali Metal Exposure Program Specimen Identification Numbers**	pecimen		
Vacuum Exposed	pesodx	Lithium Exposed	Exposed	Vacuum Exposed	Exposed	Lithium Exposed	pasodx
1000 Hours at 1800° (1255°K)		1000 Hours at (1255°K)	1000 Hours at 1800"F (1255°K)	1000 Hours at 2400'F (1589°K)	at 2400°F 9°K)	1000 Hours at 2400"F (1589°K)	at 2400"F °K)
G. E. No.	TRW No.	G.E. No.	TRW No.	G E. No	TRW No.	G.E. No.	TRW No.
01-14	ı	01-10	1	04-33	5-132	01-1	ī
01-15	•	01-12	1	04-36	5-122	01-3	1
91-10	,	04-25	i	04-37	5-121	1-40	5-127
01-17	•	04-56	ŧ	04-38	3	C+-5	,
81-10	1	04-27		04-39	:	4-40	1
99-40	•	04-59	3	14-40	5-124	04-5	i
69-40	•	04-30	•	04-45	1	7-40	ŧ
04-70	•	04-31	•	04-43	i	8-40	ı

Exposed at 2400°F 39°K) TRW No.	S-149 S-155 S-156
Lith:um Exposed 5000 Hours at 2400°F (1589°K) G.E. No. TRW No.	04-10 04-10 04-17 04-15 04-15
Vacuum Exposed 5000 Hours at 2400°F (.589°K) G.E. No. TRW No.	S-139 S-141 S-146 S-146
Vacuum 5000 Hours (.3	04-48 04-49 04-50 04-51 04-53 04-53
Lithium Exposed 1000 Hours at 1800°F (1255°K) Plus 4000 Hours at 1900°F (1310°K) G.E. No TRW No.	S = 167 S = 168 S = 168
Lithium Exposed 1000 Hours at 180((1255°K) Plus 4000 Hours at 1900 (1310°K) G.E. No TRW	04-18 04-19 04-20 04-21 04-23 04-23
Exposed at 1800°F K) Plus at 1900°F 10°K) TRW No	S S 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Vacuum Exposed 1000 Hours at 1800°F (1255°K) Plus 4000 Hours at 1900°F (1310°K) G.E. No. TRW No.	04-59 04-60 04-62 04-63 04-64

Pre-exposure creep test numbers S-'62, S-163, and S-164

* Those specimens not showing a TRL creep test number have not been tested to date.

Table 3

Influence of Heat Treatment and Liquid Metal Exposure on the Oxygen in T-111, Heat \$50050*

Condition	Oxygen Analysis, ppm
As Received	33 (average of 4 analyses)
Annealed 1 hour at 3000°F (1922°K) plus 1 hour at 2400°F (1589°K)	104 (average of 3 analyses)
Exposed to lithium 1000 hours at 1800°F (1255°K)	91
Exposed to 10 ⁻⁹ torr 1000 hours at 1800°F (1255°K)	33
Exposed to lithium 1000 hours at 2400°F (1589°K)	\$
Exposed to 10 9 torr 1000 hours at 2400°F (1583°K)	57

* Analyses performed at NASA Lewis Research Centor

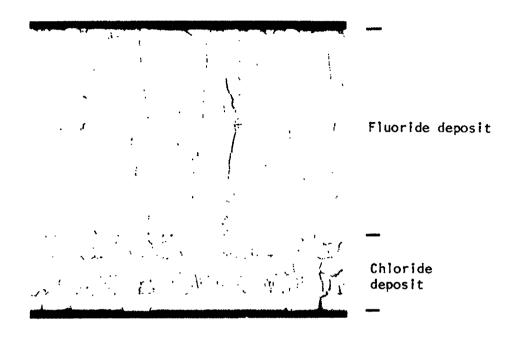


Figure 1. Photomicrograph of CVD tungsten annealed 100 hours at $3272^{\circ}F$ (1800°C).

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General Test Procedures

The experimental program is devoted to the generation of design data by creep testing sheet and bar specimens at temperatures and stresses which will provide one half to one percent creep in 2000 to 25,000 hours. Two inch gauge length, button-head bar-type specimens and double shoulder, pin loaded, sheet type specimens were used for testing of plate and sheet type materials. The orientation of the specimen with respect to the working direction is given below:

Material Form	Specimen Axis Parallel to
Disc Forging	Radius
Plate	Extruded or rolling direction
Sheet	Rolling direction (except where indicated)

Both the construction and operation of the test chambers and the service instruments in the laboratory have been described in detail in previous reports (Appendix 1). The creep test procedure involved initial evacuation of the test chamber to a pressure of less than 5×10^{-10} torr at room temperature, followed by heating of the test specimen at such a rate that the pressure never rose above 1×10^{-6} torr. Pretest heat treatments were performed in situ, and complete thermal equilibrium of the specimen was attained by a two-hour hold at the test temperature prior to load application. The pressure was always below 1×10^{-0} torr during the tests and generally fell into the 10^{-10} torr range as testing proceeded. Specimen extension was determined over a two inch gauge length with an optical extensometer which measured the distance between two scribed reference marks to an accuracy of ± 50 microinches.

Specimen temperature was established at the beginning of each test using a W-3%Re - W-25%Re thermocouple. Since thermocouples of all types are subject to a time-dependent change in EMF output under isothermal conditions, the absolute temperature during test was maintained by an optical pyrometer. In practice the specimen was brought to the desired test temperature using a calibrated thermocouple attached to the specimen as a temperature standard. The use of this thermocouple was continued during the temperature stabilization period which lasted 50 to 100 hours. At this time, a new reference was established using an optical pyrometer having the ability to detect a temperature difference of $\pm 15^{\circ}$, and this reference was used subsequently as the primary temperature standard.

RESULTS AND DISCUSSION

Presentation and discussion of the test results will be divided into topical sections concerning each of the specific materials and programs in progress. A summary of the tests conducted during this report period is presented in Appendix II together with all of the previous tests from the vacuum creep program. Creep curves for each test conducted during the current reporting period are presented in Appendix III.

T-III Test Results

The design characterization of T-III alloy has been essentially completed with only a small number of conventional T-III design tests still in progress. A Larson-Miller plot of the 1% creen life data developed from this test series is shown in Figure 2.

Results from the T-III lithium corrosion loop exposure program are presented in Table II-18 (Appendix II), and are plotted on a Larson-Hiller diagram in Figure 3. Comparison of the pre-exposure results with the T-III design band (also plotted in Figure 3) shows that the specific heat of T-III selected for these tests (Heat 650050) is significantly stronger than typical heats of this material, with the three pre-exposure tests on heat treated 650050 specimens falling near the upper limit of the scatter band for the nine previously tested heats. This result may be associated with the relatively high oxygen level resulting from the duplex heat treatment applied to this material prior to exposure.

While creep testing of the exposed specimens has been concentrated on the long time (5000 hours) exposures, a few tests have been conducted on the short time (1000 hours) exposed specimens. Both the short and long time results indicate essentially no detectable influence of exposure to vacuum or lithium at 2400°F on the creep resistance of T-III alloy, in agreement with preliminary results presented in the last report on the UHV creep program (3). However, significant and even drastic effects were found for the long exposure time specimens at the lower exposure temperatures (1800 and 1900°F). As an example of these effects, duplicate creep tests at 1800°F (1255°K) and 35 ksi (241 MN/m²) showed that a 5000 hour exposure to lithium at 1800 and 1900°F (1255 and 1310°K) reduced the 1% creep life of T-111 alloy from more than 500 hours before exposure to only 5 hours after exposure! This dramatic reduction in life of the long time lithium exposure existed over the entire 16 to 50 ksi (110 to 344 MN/m^2) and 1650 to 2200°F (1072 to 1478°K) stress and temperature range examined, but was somewhat less severe at the higher temperatures and lower stresses. Long time vacuum exposure at the lower temperatures also caused significant reduction in the creep resistance of the T-111 alloy, although in most cases the reduction in life was not as severe as that caused by exposure to lithium for the same times and temperatures.

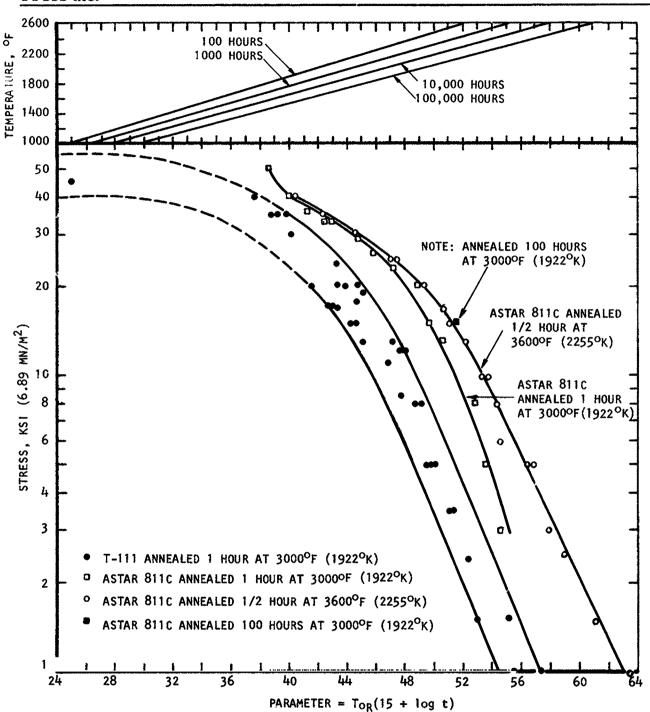


FIGURE 2. LARSON-MILLER PLOT OF ONE PERCENT CREEP LIFE FOR TANTALUM BASE ALLOYS T-111 AND ASTAR 811C.

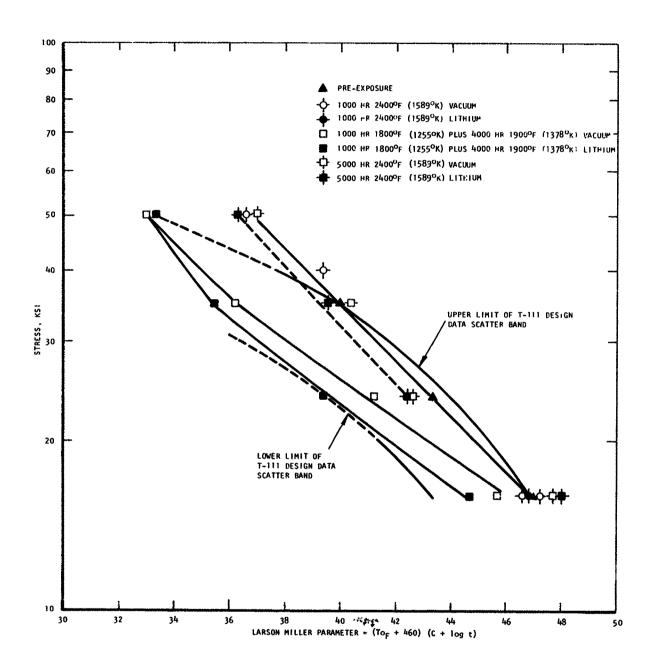


FIGURE 3. INFLUENCE OF 10-9 TORR VACUUM AND LITHIUM EXPOSURES ON THE ONE PERCENT CREEP LIFE OF T-111 ALLOY HEAT 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K).

Additional creep tests will be conducted during the coming report period on specimens exposed 1000 hours at 1800°F (1255°K) to determine if creep life reductions result from the short time exposures at this temperature. In addition, metallographic studies will be performed in an effort to determine the cause of the observed strength reductions.

ASTAR 811C Test Results

The ASTAR 811C 1% creep life data generated to date on the program are plotted on the Larson-Miller diagram in Figure 2. It should be noted that only data from the commercial heat of the ASTAR alloy are shown in this figure, with the earlier data from the laboratory heats having been omitted for the sake of clarity.

The effort to characterize the creep behavior of ASTAR 811C annealed 1/2 hour at 3600°F (2255°K) is essentially complete, with only three tests of material with this heat treatment still in progress. Preliminary results which were presented in the last report on ASTAR 811C annealed 1 hour at 3000°F (1922°K) (3) indicated that the lower annealing temperature produced a shorter creep life at temperatures above 2000°F (1366°K), but that the creep life below that test temperature was essentially in distinguishable for the two annealing treatments. Results generated during the current report period on material annealed 1 hour at 3000°F (1922°K) continue to support these observations, which are consistent with the previously discussed hypothesis (4) that the increase in creep life caused by the higher annealing temperature is primarily a grain size effect. The carbide acts predominantly as a grain boundary strengthener in each instance. Since the creep life of the ASTAR alloy was shown by Buckman (4) to be grain size dependent at and above 2400°F (1589°K) but not at 2000°F (1366°K), it seems reasonable that the strengthening achieved by increasing the grain size with a high temperature anneal would be effective only in the temperature range where grain boundary sliding occurs. In fact it may well be that the improved life at lower temperatures is predominately an alloying effect due to rhenium, which is well known to be a potent solid solution strengthening element in tantalum.

In an effort to develop additional support for the above hypothesis, a creep test has been conducted on a specimen annealed 100 hours at 3000°F (1922°K). This heat treatment is well below the carbide solvus temperature, previously shown to be between 3520 and 3560°F (2211 and 2233°K) (6), but is long enough to provide a grain size comparable to that produced by the 3600°F (2255°K) anneal for 1/2 hour. Results of this test showed a creep life comparable to that produced at the higher temperature anneal (Table 4), thereby lending further support to the theory that the influence of annealing temperature on the creep strength of ASTAR 811C alloy is essentially a grain size effect, with the carbide operating primarily as a grain boundary strengthener rather than functioning in a true dispersion hardening role.

Table 4

of ASTAR 811C Alloy, Heat 650056 Tested at 2400°F (1589°K) and 15 ksi (103 MN/m²)

Heat	Treatment	
Time Hour	Temperature °F °K	1% Creep Life, Hours
1	3000 1922	230
100	3000 1922	790
0.5	3600 2255	825

CVv Tungsten Test Results

A program has been undertaken to characterize the creep behavior of chemically vapor deposited tungsten creep specimens annealed 100 hours at $3272^{\circ}F$ ($2273^{\circ}K$). Two creep tests have been completed in this series at a temperature of $2912^{\circ}F$ ($1873^{\circ}K$) and at stresses of 0.5 and 1.0 ksi (3.5 and 6.89 MN/m²). These tests exhibited respective steady state creep rates of 3.3×10^{-7} and 7.7×10^{-7} hour¹, with extrapolated 1% creep lives of 30,000 and 13,000 hours. A third test is presently in progress at the same temperature and a stress of 2.0 ksi (13.8 MN/m²) which shows a steady state creep rate of 3.3×10^{-6} hour¹ and has an extrapolated 1% creep life of 3000 hours. The 1% creep life results for these tests are plotted on a Larson-Miller diagram in Figure 4, together with CVD tungsten results obtained at 0ak Ridge National Laboratory at a test temperature of $3000^{\circ}F$ ($1922^{\circ}K$).

Because the ORNL tests were conducted at higher stress levels than the TRW tests, a direct comparison of the results is not possible. An extrapolation of the ORNL data appears to be consistent with the high stress TRV test, but the slope of the TRW curve is significantly steeper than that of the ORNL data. While this comparison appears to indicate an instability phenomenon occurring in the CVD-tungsten test material at longer test times, the results must be interpreted with some caution as the two groups of tests were performed on two different lots of material. As additional specimens are available from the lot of material tested at TRW, it may be possible to conduct tests on this material at higher stress levels to resolve this uncertainty concerning the creep behavior of CVD tungsten.

Molybdenum Base Alloy TZM

Only one TZM alloy test was in progress during the current reporting period on a specially processed lot of TZM which had a higher than normal carbon content and was forged in the $3400^{\circ}F$ ($2144^{\circ}K$) range to produce an improved carbide dispersion. This test at $2000^{\circ}F$ ($1366^{\circ}K$) and 22 ksi (15.1×107 MN/m²) reached 1/2% creep at 16,293 hours, which is significantly longer than anticipated for conventional TZM. While a TZM test would normally be discontinued at 1/2% strain, this test is being continued beyond that point to determine a 1% creep life and to check for possible creep rate instabilities at higher strain levels.

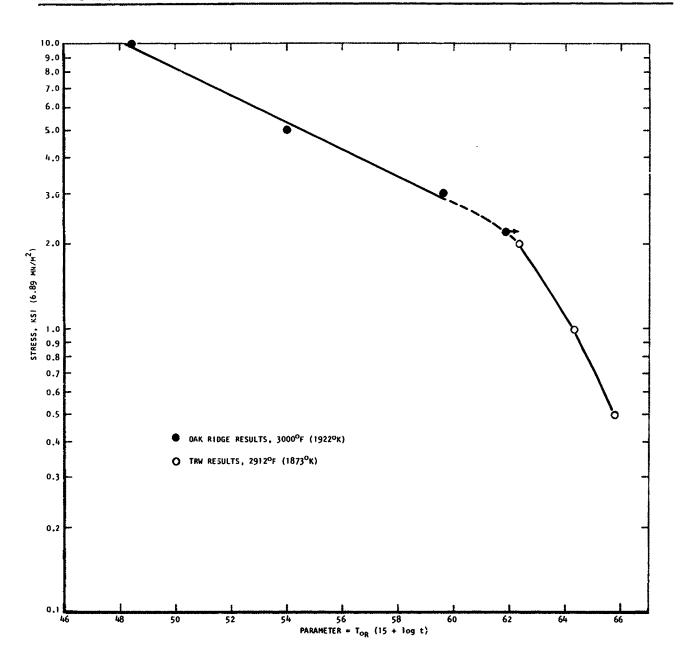


FIGURE 4. ONE PERCENT CREEP LIFE RESULTS FOR CVD TUNGSTEN

CONCLUSIONS

Significant conclusions reached during the current report period are:

- 1. Exposure of T-111 alloy to 10^{-9} torr vacuum or to liquid lithium for 5000 hours in the 1800 to 1900°F (1265 to 1310°K) range significantly reduces the creep life of this material. Comparable exposures for 1000 and 5000 hours at 2400°F (1589°K) appear to have little or no effect on the T-111 creep life.
- 2. The creep life of ASTAR 811C alloy appears to exhibit significant grain size dependence above the equicohesive temperature of 2000°F (1366°K), with heat treatments of 1/2 hour at 3600°F (2255°K) and 100 hours at 3000°F (1922°K) providing significantly longer creep lives than a heat treatment of 1 hour at 3000°F (1922°K).
- 3. A potential instability has been detected in the creep behavior of CVD tungsten which requires further investigation.
- 4. Results from a specially processed heat of TZM alloy (Heat KDTZM-1175) having a higher than normal carbon content and forged at higher than normal temperatures continue to show a creep strength superior to conventional TZM alloy.

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- 2. R. L. Salley and E. A. Kovacevich, 'Materials Investigation, SNAP 50-SPUR Program, Mechanical Properties of TZM," Technical Report AFAPL, 25 June 1965.
- 3. K. D. Sheffler, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Final Report, Contract NAS-3-13469, TRW ER-7541, NAS-CR-72997, 20 May 1971.
- 4. K. D. Sheffler, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Semi-Annual Report, Contract NAS-3-13469, TRW ER-7506, NAS-CR-72871, 16 November 1971.
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- 6. K. D. Sheffler, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Seventeenth Quarterly Report, Contract NAS-3-9439, NASA-CR-72523, 15 October 1968.

APPENDIX I

PREVIOUSLY PUBLISHED REPORTS

ON THE REFRACTORY ALLOY CREEP PROGRAM

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APPENDIX II

SUMMARY OF ULTRAHIGH VACUUM CREEP TEST RESULTS GENERATED ON THE REFRACTORY ALLOY CREEP PROGRAM

Summary of Arc-Melted Tungsten Ultra-High Vacuum Creer Test Results TABLE II-1.

								;	•		
Test No.	Heat No.	Heat Time Hours	Treatment Temperature	ent ature ok	Stress KSI BN	ess BN/M2	Test Temperature or ok	1% Creep Life Hours	Termination of Test Time, Percy	nation Fercent Creep	1% Creer Larson-Miller Parameter (Tog 15+lcgt x10-3)
S-5	KC-1357	24	3200	2033	3.0	20.7	3200 2033	ø	32	5.38	57.8
S-7	KC-1357	8	3200	2033	† 0	2.8	3200 2033	*	714	118	* *
8-8	KC-1357	8	3200	2033	1.0	6.9	3200 2033	675	3886	2.760	65.4
S-17	KC-1357	N	2800	1811	0.4	28.0	2800 1811	20	806	5.452	53.1
S-18	KC-1357	73	2800	1811	3.0	20.7	2800 1811	125	806	5.535	55. 8 8

***Insufficient creep to extrapolate

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Summary of Vapor-Deposited Tungsten Ultra-High Vacuum Test Results TABLE II-2.

# # # # # # # # # # # # # # # # # # #	Heat No.	î. GB		Treatment Temperature of	Stre	Stress I MNM2	Test Temperature OF OK	1% Creep Life Hours	Termination of Test Time, Ferc	e a t	larscn-Miller Parameter (Tog 15+logt x10-3)
B-17	ŧ	~	3200	2033	1.0	6.9	3200 2033	1140	2671	1.570	0.99
B-24	i	H	2800	1811	2.0	13.8	2800 1811	1500	6812	3.708	59.2
s-102	i	100	3272	2273	0.5	3.5	2912 1873 30,000*	30,000*	2811.5 0.037	0.037	65.8 8
s-117	:	100	3272	2273	1.0	6.9	2912 1873 13,000*	13,000*	5400	9##*0	64.3
s-150	;	100	3272	2273	2.0	2.0 13.8	2912 1873	3,000*	*	* *	62.3

*Extrapolated

Summary of Tungsten-25% Re Ultra-High Vacuum Creep Test Results TABLE II-3.

4 6 8		Heat		ent	ć	ļ	Test	Creep		icr	1% Creer Larscn-Miller
NO.	Heat No.	Hours	remperature of	ardire Ox	KSI	Stress I MN/M2	remperature of ok	Lite	Time, Hours	Fercent	Top 15+logt x10-3)
8-3	3.5-75002	8 #	3200	2033	ა. ა	34.4	3200 2033	12	45	6.03	58.9
S-4	3.5-75002	45	3200	2033	3.0	20.7	3200 2033	25	45	5.22	0.09
9-8	3.5-75002	-	3200	2033	0.5	3.4	3200 2033	* *	253	050.3	**
8-8	3.5-75002	-	3200	2033	1.5	10.3	3200 2033	315	1306	5.113	0*19
S-55A	3.5-75002	-	2550	1673	10	68.9	1600 1144	:	200	0.005	ŝ Į
S-55B	3.5-75002		î Î		10	68.9	1650 1172	i	203	0.005	į
S-55C	3.5-75002		;		10	68.9	1700 1200	\$ I	196	0.008	Į į
s-55D	3.5-75002		! !		10	68.9	1750 1228	i i	241	0.018	* 1
S-55E	3.5-75002		!		10	68.9	1800 1255	1	257	0.035	i i
S-61A	3.5-75002		i !		15	100.4	1600 1144	i	235	0.008	3 6
S-61B	3.5-75002		!		15	100.4	1650 1172	ľ	169	0.022	1
S-61C	3.5-75002		į	•	15	100.4	1700 1200	1	196	0.038	3
g-61D	3.5-75002		į		15	100.4	1750 1228	1	200	6.058	\$
S-61E	3.5-75002		;		15	100.4	1800 1255	į	194	0.078	ŀ

***Insufficient creep to extrapclate

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Summary of Sylvania A Ultra-High Vacuum Creep Test Results TABLE II-4.

0	ហ		2 3200 2033 5.
20.7	3.0 20.7		3200 203
	ب ص ح	203	3200 203 3200 203
3200 203	O O	1 1	

TABLE II-5. Summary of AS-30 Ultra-High Vacuum Creep Test Results

Hest Most	Heat WO.	H田	Beat Treatment ime Temperature Jours OF OK K	Str	Stress KSI MN/M2	Test Temperature op ok	1/2% Creep Life Hours	Termination of Test Time, Fero	10 W	ttion 1/2% Creep sst Larson-Miller Fercent Farameter Creep (Tog 15+logt x10-3)
B-2	S	As-R	As-Rolled	12.0	82.7	12.0 82.7 2000 1366	390	908	1.020	43.3
9-8	ដ	æ	As-Rolled	11.0	75.8	11.0 75.8 2000 1366	450	1192	1.016	8° °C †
8-7	CS	As-B	As-Rolled	8.0	55.1	8.0 55.1 2200 1478	115	230	1.025	ក• នក

Table II-6. Summary of Cb-132M Ultra-High Vacuum Creep Test Results

## ## 0 ## 0 ## 0 ## 0 ## 0 ## 0 ## 0	Heat Mo.	Heat Time Hours	Heat Ireatment me Temperature urs or	ent ature ox	Str	Stress KSI MW/M2	Test Temperature of	ture K	1/24 Creep Life Hours	Terminati of Test Time, Pe Hours C	Termination of Test ime, Fercent ours Creep	tion 1/2% Creep st Larson-Miller Fercent Farameter Creep (T og 15+logt x10-3)	
B-13	B-13 KC-1454	-	3092	1973	20.0	138.0	1973 20.0 138.0 2056 1398	861	275	568	1.170	e. e. a.	
B-14	RC-1454	H	3092	1973	16.3	82.3	1973 16.3 82.3 2056 1398	861	340	691	1.026	0 * ħ ħ	
- C	8-15 KC+1656	,	3092	1973	7.4	51.0	3090 326 1508	80	250	250 596 1,100	1,100	27.7	

Summary of T2M Ultra-High Vacuum C.eep Test Results

		Heat	Treatmont	+			÷	1/2%	Termination	ation	1/2% Creep
rest xo.	Heat No.	Time Hours		ature oK	Stress KSI mw/	ess ens ens	Temperature of ox	Life Hours		rest Fercent Creep (Larsch-miller Farameter (T.eg.15+logt x10-3)
B-1	7502	-	2200	1478	12.6	86.5	2130 1439	605	9 11 9	1.105	46.1
B-3	7562	~	2200	1478	10.0	68.9	2000 1366	14,200*	1C, C48	0.375	47.1
в-29	7502	1	2200	1478	41.0	282.0	2000 1366	100	1799	6.215	41.8
8-35	7502	p=4	2200	1478	0.44	303.0	1800 1255	7000	7659	0.535	42.6
B-4	7502	pref	2200	1478	10.0	68.9	2000 1366	25,000*	10,012	C.368	47.7
		-	2850	1839							
B-16	KDT28-1175	H	2300	1533	23.4	161.0	1855 1286	62,500*	4376	0.035	45.8
B-18	KDTZ8-1175	~	2300	1533	55.0	379.0	1600 1144	*000*09	2159	0.018	46.7
B-21	RETZH-1175	н	2300	1533	65.0	448.0	1600 1144	15,000*	1630	0.085	39.5
8-25	KDTZH-1175	~	2300	1533	0.44	303.0	1800 1255	\$000,03	16,152	0.182	44.5
B-38	KD128-1175		2300	1533	22.0	151.0	2000 1366	16,293	* *	*	47.1
8-34	7463	1/2	2250	1505	41.0	282.0	2000 1366	790	1440	1.658	0.44
*Extr	*Extrapolated data	et e									

**Test in progress

Summary of Cb Mcdified T2M Ultra-High Vacuum Creep Test Results TABLE II-8.

		4 0 2		+			ŧ	+ 0 0+	1/2%	Termination of Test	nation	1/2% Creep
Test No.	Heat No.	Time Hours	Temperatu OF	ature ok	Stress KSI MN	ess BN/B2	Tempe	Temperature of ok	Life Hours	Time, Hours	cent	£
B-23A	4305-4	гd	2500	1644	20.0	20.0 138.0	2000 1366	1366	*000*07	989	0.032	47.5
B-23B	4305-4	1	:	ŀ	28.0	28.0 193.0	2000 1366	1366	10,000*	307	C.C28	46.7
B-23C	4305-4	ı	i	1	40.0	40.0 276.0	2000 1366	1366	630*	185	0.188	43.8
B-23D	4365-4	1	:	i i	0.94	317.0	1800 1255	1255	#000#	403	0.078	42.0
B-23E	4305-4	ı	ţ	:	34.0	34.0 234.0	2100 1422	1422	1000*	329	0.170	46.1
B-27	4305-4	-	2500	1644	41.0	41.0 282.0 2000 1366	2000	1366	1090	1584	1.040	44.5

*Extrapolated

Summary of T2C Ultra-High Vacuum Creep Test Results TABLE II-9.

			+ 0 11	Trea+ =01	- -			÷	1/2%	Termination	nation	1/2% Creep
Test No.	Beat	No.	Time Hours		ature	Stress KSI #N	ESS EN EN E	Temperature of or	Life Hours		Fercent Creep	parameter (T og 15+1cgt x10-3)
B-8A	M-80		H	3092	1973	18.0	124.0	2200 1478	1100	2128	1.060	48.3
B-10	M-80		Ħ	3092	1973	17.0	117.0	2200 1478	2500	2749	6.545	6.84
88	M-80		r-1	3092	1973	20.0	138.0	2000 1366	10,408	16,002	0.670	46.8
B-11	M-80		н	3092	1973	25.0	172.0	1856 1287	75,000*	14,406	0.182	46.0
B-12	M-80		Ħ	3092	1973	19.0	131.0	2056 1398	15,000*	14,239	0.280	49.2
B-20	M-91		н	3092	1973	20.0	138.0	2000 1366	3650	12,795	1.008	45.7
B-31	H-91		п	3092	1973	14.0	96.5	2200 1478	329	912	1.092	46.6
B-19	₩-91		М	2300	1533	0.44	303.0	1800 1255	1075	#09#	1.015	41.1
B-28	M-91		1	2300	1533	28.0	193.0	2000 1366	1100	4214	1.138	n•nn
B-30	H-91		н	2500	1644	22.0	152.0	2200 1478	70	259	1.280	8 * 71 77
B-32	M-91		m	2500	1644	20.0	138.0	1935 1330	14,400	16,130	0.535	45.9
B-33	H −91		н	2500	1644	22.0	152.0	11800 1311	7720	7696	0.585	9.44
B-36	4345		1	2500	1644	22.0	152.0	2000 1366	2940	8563	0*9*0	46.2
B-37	4345		1	2400	1589	22.0	152.0	2000 1366	8853	9020	0.500	46.3
*Extra	*Extrapolated	ğ										

Summary of T-222 Ultra-High Vacuum Creep Test Results TABLE II-1C.

Hest Host	Heat No.	Heat Time Hours	Heat Treatment me Temperature urs Of	ent ature or	Stress KSI BW	Stress KSI #W/K2	Test Temperature of ok	1% Creep Life Hours	Termination of Test Time, Perc Hours Cre	ation est Percent Creep	ion l% Creep t Larson-Miller ercent Parameter Creep (I og 15+logt x10-3)
s-13	AL-TA-43	н	3000	1922	12.0	82.7	1922 12.0 82.7 2200 1478	560	1890	5.720	47.2
S-14	AL-TA-43	н	3000	1922	19.2	132.0	1922 19.2 132.0 2056 1398	890	1314	1.685	45.1
8-20	AL-TR-43	p=4	2800	1811	12.0	82.7	1811 12.0 82.7 2200 1478	405	1389	5.060	6.94

Summary of ASTAR 811C Ultra-High Vacuum Creep Test Results TABLE II-11.

		Ē					,	*	H	ticn	1 (Creep
Test No.	Heat No.	Heat Time Hours	Treatment Temperature or or	ment cature or	Str	Stress	Temperature or	Creep Life Hours	of Te Time, Hours	est Fercent Creep	Larson-Miller Parameter (T og 15+1cgt x10-3)
s-29	NASV-20-WS	r.	3600	2255	2.C	13.8	2600 1700	21,190	21,560	1.028	59.3
s-7c	VAM-95	.25	3520	2211	20	138.0	2100 1422	3600*	983.4	C.342	47.5
S-71	VAM-95	13.	3600	2255	20	138.0	2100 1422	3600 *	767.5	0.320	47.5
S-70A	VAM-95	t	•	1	15	103.0	2200 1478	*0009	655.8	0.108	20.0
S-71A	VAM-95	t	!	;	15	103.0	2200 1478	*0009	678.9	0.112	50.0
S-70B	VAM-95	ı	!	1	10	0.69	2300 1533	*0009	1106.4	0.153	51.9
S-71B	VAM-95	ŧ	!	i	10	0.69	2300 1533	*0009	1082.2	0.178	51.9
s-73	VAM-95	•33	3600	2255	15	103.0	2400 1589	435	720.5	1.860	50.5
S-74	650056	.33	3600	2255	15	103.0	2400 1589	825	1466.0	2.185	51.2
s-75	VAM-95) • H	3000	1922	15	103.0	2400 1589	144	162.3	1.195	1.64
3-76	650056	ທຸ	3600	2255	25	162.0	2175 1464	695	4962.5	15.088	47.0
S-77	650056	ស្	3600	2255	10	0.69	2400 1589	5287	5907.9	1.150	53.6
8-78	650056	ស្	3600	2255	v n	35.0	2550 1672	5611	6210.4	1.210	56.6
s-79	VAM-95	ហ	3450	2172	15	103.0	2400 1589	542	714	1.378	50.8
s-81	VAM-95	24	3270	2012	15	103.0	2400 1589	260	666.5	1.330	50.8
S-85	650056	ស	3600	2255	20	138.0	2175 1464	4410	5346.7	1.240	1.54
S-86	650056	ស	3600	2255	15	103.0	2300 1533	4390	5206.1	1.240	51.1
1											

*Extrapolated

Summary of ASTAR 811C Ultra-High Vacuum Creep Test Results TABLE II-11.

1% Creer Larscn-Miller Farameter (T og 15+1cgt x10-3)	48.1	49.1	52.1	52.3	42.2	S*1111	47.2	57.9	40.2	54.3	58.9	61.1	9.64	54.5	55.2
n cent eer	11.470	16.750	1.206	1.506	2.402	2.018	1.095	3.798	*	2.392	3,552	4.918	12.162	1.160	1.022
Terminatics of Test Time, Per	329	330.9	1777.0	2851.9	4323.6	6385.0	6763.6	4364.0	*	3963.8	5303.4	4504.7	673.9	2971.2	4512.8
1% Creep Life Hours	89	152	1575	1894	1858	2656	6095	2064	35,000*	2266	2270	1580	230	2778	4420
Test Temperature of oK	2400 1589	2400 1589	2400 1589	2400 1589	1850 1283	1950 1339	2050 1394	2700 1755	1600 1144	2500 1644	2750 1783	2900 1866	2400 1589	2500 1644	2500 1644
Stress	103.0	103.0	55.1	55.1	241.0	207.0	162.0	20.7	276.0	55.1	16.2	10.3	103.0	41.4	48.2
st KSI	15	15	œ	Ø	35	3 C	25	m	40	ω	2.5	1.5	15	9	7
Treatment Temperature of	1922	1922	1922	1922	2255	2255	2255	2255	2255	2255	2255	2255	1922	2255	2255
	3000	3000	3000	3000	3600	3600	3600	3600	3600	3600	3600	3600	3000	3600	3600
Heat Time Hours	~	-	H	н	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	н	0.5	0.5
Heat No.	NASV-20	S-100++NASV-20	NASV-20	S-1C8++NASV-20	920059	650056	650056	650056	950059	950059	950059	920029	950059	950059	650056
He se to the se	S-87+	s-100+	S-104+	S-108+	06-S	8-91	26-8	5-93	8-94	S-95	96-S	2-97	S-101	S-106	s-112

+Post Exposure Samples From G.E. Alkali Metal Exposure Program ++Pre-Exposure Samples From G.E. Alkali Metal Exposure Program

*Extrapolated **Test In Progress 21

Summary of ASTAR 811C Ultra-High Vacuum Creep Test Results TABLE II-11.

		# # #	Treatment	lent			e.	1% Creen	Termin	Termination of Test	1% Creep
Test No.	Heat Wo.			ature ok	St1 KSI	Stress II MW/M2	Temperature or ox			Fercent	Parameter (T og 15+logt x10-3)
s-113	950059	0.5	3600	2255	ιΩ	34.4	2500 1644	11,000*	*	*	56.4
5-114	650056	0.5	3600	2255	m	6.9	2900 1866	7380	7728	1.052	63.4
S-118	950059	r-1	3060	1922	53	8.261	2000 1366	1620	1655.3	1.010	8 * 11 17
8-119	950059	0.5	3600	2255	10	68.9	2500 1644	1035	1145.3	1.178	53.3
s-120	650056	0.5	3600	2255	13	85.5	2300 1533	7250	*	*	52.1
s-123	950059	0.5	3600	2255	17	117.0	2300 1533	2225	2257.3	1.015	50.6
s-125	920059	~ 1	3000	1922	23	158.3	2000 1366	*	*	*	**
s-126	650056	н	3006	1922	26	179.0	2000 1366	4360	4633	1.052	45.8
s-128	650056	Ħ	3000	1922	36	248.0	1600 1311	290	649	1.390	41.2
s-129	920059	н	3000	1922	សា	34.4	2600 1700	300	435.4	1.762	អ ខ ខ
s-131	950059	-	3000	1922	2	276.0	1800 1255	580	866.5	1.145	40.1
5-134	650056	н	3000	1922	33	234.C	2000 1366	180	353.5	1.552	42.4
s-135	650056	- 1	3000	1922	13	89.7	2400 1589	210	531.3	1.040	50.6
s-136	650056	Ħ	3000	1922	23	159.0	2200 1478	200	5009	1.008	47.C
s-138	650056	100	3000	1922	15	103.0	2400 1589	190	934.2	1.245	51.1
1											

*Extrapolated **Test In Progress ***Insufficient to Extrapolate

Sunmary of ASTAR 811C Ultra-High Vacuum Creep Test Results TABLE II-11.

£-		Heat Time	Beat Treatment	ent	* *	0 0 4 0	Test	Creep	Termination of Test	ation	1% Creep Larson-Miller
.0	Heat No.	Hours	No N) 10 12 14	KSI	ZW/NH	No Ho	Hours	HOURS	Creep	creep (Top 15+10gt x10-3)
5-142	650056	.	3000	1922	20	344.0	344.0 1600 1144	*0005	*	*	38.5
8-143	650056	-	3000	1922	18	124.0	124.0 2200 1478	2800	*	*	1.64
S-144	650056	-	3000	1922	υO	55.2	55.2 2400 1589	2575	*	*	52.7
5-147	650056	7	3000	1922	m	20.6	20.6 2600 1700	740	1033.9	1.760	54.6
S-160	650056	н	3000	1922	33		228.0 1500 1311	1340	*	*	42.8

*Extrapolated **Test In Progress

Summary of T-111 Ultra-High Vacuum Creep Test Results TABLE II-12.

	********				******	-												
1% Creef Larscn-Miller Parameter (T og 15+lcgt x10-3)	47.5	48.7	48.0	47.7	43.8	43.3	9*44	42.9	ທ ເກ •	63.7	45.0	5.64	42.8	49.1	6*9#	46.3	42.7	
naticn Test Percent Creep	2.570	3,368	6.548	1.225	2.010	1.090	1.210	1.030	C.632	C.568	2.C82	1.042	1.028	1.048	1.010	1.230	1.070	
Termination Of Test Time, Perc	1675	0.4870	3840	3698	1099	911611	1584	9624	482	38,129.3	3459	4322	8717	2976	10,875	274	8728	
1% Creep Life Hours	725	2000	1140	3150	670	4730	1340	9540	1100*	+000,019	1880	4050	8558	2850	10,800	260	8202	
Test Temperature of ox	2200 1477	2200 1477	2200 1477	2120 1433	2000 1366	1860 1289	2000 1366	1800 1255	2600 1700	2600 1700	2000 1366	2200 1477	1800 1255	2200 1477	2000 1366	2200 1477	1800 1255	
ess en/es	55.1	55.1	82.6	82.6	138.0	138.0	103.0	11.7.0	10.3	3.4	89.5	34.4	117.0	55.1	75.8	55.1	89.5	
Stress KSI BN	8.0	8.0	12.0	12.0	20.0	20.0	15.0	17.0	1.5	0.5	13.0	5.0	17.0	8.0	11.0	8.0	13.0	
Treatment Temperature of or	1700	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	
	2600	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	
Heat Time Hours	H	Ħ	Ħ	н	H	7	7	г	~	-	H		H	~	-4	, - 1	-1	
Heat No.	70616	70616	70616	70616	70616	70616	D-1670	D-1670	D-1670	D-1670	p-1102	D-1102	D-1102	65076	92259	65080	65080	*Extrapolated
Test No.	91-s	8-19	s-21	s-23	s-22	S-24	s-25	s-26	S-25A	S-28	5-27	s-32	8-40	8-33	S-34	S-37	8-39	*Extr

TABLE II-12. Summary of T-111 Ultra-High Vacuum Creep Test Results

į		Beat 1		ent	i d	\$ \$	# H	Test	C L L L L L L L L L L L L L L L L L L L		nation Test	1% Creep Larson-M.ller
Test.	Beat No.	Hours		9 C C C C C C C C C C C C C C C C C C C	KSI EN	22./22. 22./22.2	ກ ສະທະ ກ		Hours	Hours	Creep	(T og 15+logt x10-3)
8-45	65080	-	3000	1922	3.0	20.0	7.200	1477	554	169	1.165	47.1
s-30	62039	н	3000	1922	3.5	24.1	2400	1589	860	2137	2.372	51.3
s-31	62039		3000	1922	5.0	34.4	2200	1478	6160	6594	1,692	50.0
S-35	62019	H	3000	1922	S. 0	34.4	2200	1478	2400	5522	1.048	6*6#
S-42	62019	м	3000	1922	3.5	24.1	2300	1533	3810	4247	1.122	51.3
S-47	62079	m	3000	1922	24.0	165.0	1750	1228	19,896	22,476.2	1.298	45.43
S-48	62019	-	3000	1922	2.4	165.0	2330	1550	5500	6284	1.200	52.3
s-50	6£019	, i	3000	1922	8.5	72.2	2000	1366	24,000*	5735	0.272	47.7
S-43	65079	1/4	3000	1922	18.0	124.0	2000	1366	1500#	361	0.108	44.7
S-44A	62079	H	3000	1922	9 8	65.5	2172	1462	3250*	467	0.152	48.7
S-44B	62079	1/4	3000	1922	3.3	22.7	2371	1573	2030*	335	0.168	51.9
S-44C	62079	1/4	3000	1922	18.0	124.0	2000	1366	1670*	1146	0.688	44.8
S-44D	62079	1/4	3000	1922	23.0	158.0	1800	1255	14,650*	1391	0.112	43.3
8-59	D-1183	7	3000	1922	13.0	89.5	2000	1366	13,350	15,219.0	1.192	47.1
S-60	r-1183	н	3000	1922	35.0	241.0	1600	1144	8550	17,794.5	11.218	39.0
8-68	650028	н	3000	1922	1.0	6.9	2560	1678	2300	14,783.9	1.660	55.5
*Extra	*Extrapolated											

TABLE II-12. Summary of T-111 Ultra-High Vacuum Creep Test Results

Hest Host	Heat #0.	Heat Time Hours	Treatment Temperatur of ox	ment cature ox	Stress KSI HW	ess RE/RE	Tempera	rest remperature of ox	1% Creep Life Hours	Termination of Test Time, Ferc Hours Cre	nation Test Fercent Creep	larscn-Miller Parameter (T og 15+lcgt x10-3)	
8-69	650028	Ħ	3000	1922	30.0	207.0	1625	1158	16,625 1	18,120.7	1.312	40.1	
8-43	650028	7	3000	1922	20.0	138.0	2000	1366	1623	1640.8	1.012	8-44	
3-44	650038	7	3000	1922	35.0	241.0	2000	1366	1093	55.1	7.582	39.8	
1-d	8049	-	3000	1922	19.0	131.0	2000	1366	2070	3649	2.142	45.1	
s-80	650028	H	3000	1922	37.0	255.0	1300	978	*	3192.8	6.175	*	
S-82A	650028	•	•	!	50.0	344.0	006	755	* *	5610.8	0.075	*	
S-8.	650028	7	3000	1922	45.0	310.0	1100	998	7	1177.1	2+945	24.8	
S-8	650028	-	3000	1922	1.5	10.4	2400	1589	3250	5273.6	1.502	52.9	
S-41	65080	15	3000	1922	8.0	55.1	2200	1478	234	259	1.080	46.2	
86-S	848001	H	3000	1922	-	6.9	2560	1678	12,000*	8438.7	0.602	57.4	
8-99	650028	-	3000	1922	0.5	3.5	2700	1455 2	250,000*	9045	0.350	64.5	
8-103	650028	-	3000	1922	0	276.0	1500	1089	20,000*	*	*	37.8	
s-105	650028	4	3000	1522	35	241.0	1700	1200	1060	3211.6	8.990	39.0	
s-107	848001	4	3000	1922	20	138.0	1900	1311	380	1197.6	3.042	43.5	
s-115	848001	7	3000	1922	17	117.0	1900	1311	2100	2106.7	1.002	43.2	
s-116	848001	 1	3000	1922	15	103.3	1900	1311	2400	5472.0	1.018	44.2	
*Bxt	*Extrapolated		**Test	H.	Progress		***	***Insufficient	to	Extrapolate	ā		

TABLE II-13. Summary of I-111 Linearly Increasing Stress Ultra-High Vacuum Creep Test Results

				9	יסטיבעני יימאריט יימאריט יימאריט	100	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2			
# # # # # # # # # # # # # # # # # # #	Head to Section 1	Hert Time	Treatment Temperature OF	ent ature og	Stress Rate PSI/Hr	Test Tespera or	Test Temperature or	1% Creep Life Hours	Termination of Test Time, Perc	nation Test Percent Creep
s-36	65080	-	3000	1922	16	2200	1478	009	624	1.120
S-38	65080	~	3000	1922	٦	2200	1478	3830	9897	1.562
S-46	62039	-	3000	1922	16	2200	1478	1000*	761	0.225
8-49	62019	-	3000	1922	20	1800	1255	1660	1961	5.125
S-51	D-1183	-	3000	1922	16	2200	1478	1080	1274	5.823
S-52	62019	-	3000	1922	13	2000	1366	1596	1657	1.150
S-53	62019	-	3000	1922	Ŋ	2200	1478	2240	2970	5.292
\$-54	62029	~	3000	1922	เก	2000	1366	3850	6506	6.478
S-56	62029	-	3000	1922	ß	1800	1255	5500	6375	5.280
5-57	62039	~	3000	1922	ч	2200	1478	7748	8833	1.510
s-62	62019	-	3000	1922	7	2000	1366	8300	8599	1.150

*Extrapolated

Summary of Fure Ta Ultra-High Vacuum Creep Test Results TABLE II-14.

		1					1		18	•~	aticn	1% Creer
Test Vo.	Heat No.	Heat Time Hours	Ireatment Temperatur OF OX	ment rature ox	Stress KSI MW	ESS MX/M2	Test Tesperature Or	ature ok	Creep Life Bours	of Te Time, Hours	Test Fercent Creep	Larscn-Killer Parameter (T og 15+1cgt x10-3)
¥6€ - □	B-1962	-	1832	1273	13.6	93.7	1100	998	31	32	1.020	25.8
3-393	1962	1/4	1832	1273	11.6	79.9	1100	998	* £09	264	0.542	27.8
B-39C	B-1962	1/4	1832	1273	7 01	69.5	1183	912	463*	282	0.635	29.0
B-+0A	B-1962	н	18.2	1273	7.0	48.3	1350 1	1005	δ	5	1.000	26.9
8-408	B-1962	1/4	1832	1273	4.9	33.8	1350 1	1005	*0099	1386	0.300	34.0
8-41	B-1962	7	1832	1273	11.1	76.5	1100	866	144	160	1.078	26.7
B-42A	B-1962	-	1832	1273	4.0	27.5	1350 1	1005	170	186	1.015	31.2
B-42B	E-1962	1/4	18 12	1273	0.4	27.5	1350 1	1005	2070	1775	0.892	33.1
3-45	60243	0.1	22.90	1528	0.4	27.5	1350 1	1005	*	69.6	0.002	* *
8-458	60249	0.1	2290	1528	8.0	55.0	1350 1	1005	520	1800	1.823	32.0
8-46	60249	0.1	2296	1528	6.5	8 * 71	1350 1	1005	5600*	155.8	6.215	34.0
B-47++	60249	£: 0	2290	1528	16 Fsi/hour	hcur'	1350 1	1005	544	548.3	1.050	!
B-47A	60243	•	;	1	8.0	55.0	1350 1	1005	714	206	1.190	32.3
B-487+	60246	0.1	2290	1528	6.5	44.8	1450 1	1061	252	2371	2.885	33.2
4	•					ı	;					

*Extrapolated +Welded ***Insufficient creep to extrapclate ++Linearl

+Welded ++Linearly increasing stress

Summary of Pure Ta Ultra-High Vacuum Creep Test Results TABLE II-14.

		Beat	: Treat	went			rest		1% Creep	-74	naticn Test	1% Creer Larson-Miller
Test No.	Heat No.	Time	Terro	Temperature or	Stress KSI BN	SS BN/B2	Temperature OF OK		Life Hours	Time, Hours	Fercent	(T og 15+logt x10-3)
B-48B+	60249	1	1	i	7.5	52.3	1450 1061	1 9	150	1177.2	3.212	32.8
8-43	60249	0.1	2290	1528	6.5	8.44	1450 1061	61	92	2175.4	3.372	32.4
B-49A	60249	1	1	1	7.5	52.3	1450 1061	61	180	1363.9	3.282	33.0
B-49B	60249	ŧ	1	t i	0.6	62.1	1450 1061	61	77	497.8	5.698	31.3
B-51	60379	0.1	2290	1528	6.5	8 • 11 11	1350 1005	92	56	2712.C	4.412	29.8
B-52	60065	0.1	2290	1528	6.5	8.44	1350 1005		17,000*	2062	0.115	34.8.
B-53	60381	0.1	2290	1528	6	8.44	1350 1005		12,000*	630.9	0.858	. ; e f)
p-2	818072	:	‡	:	6.5	44.8	1350 1005	05	1.6	649.7	4.685	27.5
p-3	B-1960	:	+	;	6.5	8.44	1350 1005	95	09	6096.2	3.168	30.4
b −d	B-1960	:	‡	‡	6.5	8 - 11 11	1350 1005	05	30	5689.4	4.230	29.8
P5	B-1960	‡	‡	‡	6.5	8 * 11 17	1350 1005		110,000*	4900.5	0.155	36.3
*RXtr:	*Extrapolated	30% in ten	tension prior		to testing		+Welded ++Wot available	ailabl	v			

Summary of Ia-10W Ultra-High Vacuum Creep Test Results TABLE II-15.

									7%	Termination	laticn	1% Creer
Test No.	Beat No.	Heat Time Hours	Heat Treatment me Temperature urs of of	ent ature ok	Stress KSI MN	ess NN/N2	7 e 7 e 7 e 7 e 7 e 7 e 7 e 7 e 7 e 7 e	Test Temperature OF OK	Creer Life Hours	of Test Time, Per Hours Cr	lest Fercent Creep	Larscn-Miller Parameter (T og 15+lcgt x10-3)
S-58A	630002	н	3000	1922	20	38.0	38.0 2100 1422	1422	285	308	1.125	L* ##
S-58B	630002	1/4	3000	1922	11.5	79.3	79.3 2210 1483	1483	170*	410	0.572	47.7
S-58C	630002	1/4	3000	1922	6.2	42.7	42.7 2320 1544	1544	2200*	700	0.330	51.0
S-58D	630002	1/4	3000	1922	3.5	24.1	2430 1605	1605	10,200*	1290	0.202	54.9
s-64	630002	н	3000	1922	16	111.0 2000 1366	2000	1366	250	266	1.060	8*2#
3-66	630002		3000	1922	16	111.0	2000 1366	1366	135	550	5.150	42.1
2-67	630002	Ħ	3000	1922 12	12	02.9	02.9 2000 1366	1366	5227	8609	1.270	46.0

*Extrapolated

Summary of T-111 Linearly Decreasing Temperature Ultra-High Vacuum Creep Test Results TABLE II-16.

Test No.	Heat Mo.	Heat Time Hours	Treatment Temperature OF	ent ature or	St SS	St	Starting Test Temperatu	Starting Test Temperature or or	1% Creep Life Hours	Termination of Test Time, Fercent Bours Creep	ticn est Fercent Creep	Rate of Temperature Decrease Fo/br
S-65	s-65 65079	H	3000	1922	7	48.2	48.2 2400 1589	1589	1	1850	C-105	9•0
s-72	S-72 650028	н	3000	1922	7	48.2	48.2 2400 1589	1589	370	1322-1 1.282	1.282	0.3
S-82	s-82 650028	-	3000	1922	31	214.0 1900 1311	1900	1311	235	2013.8 1.180	1.180	ស • •

TABLE II-17. Summary of T-111 Exponentially Varying Stress and Temperature Ultra-High Vacuum Creep Test Results

ation [est Percent Creep	-0.220	0.318	1.145	-0.112	0.380	* *	0.795	1.060	2.702	1.445	*	# #
	0 -		Ä	0	ပ်	•	Ö	Ä	7	Ä	*	*
Termination of Test Time, Perce Rours Cree	166.5	173.6	310.0	454.0	1030.0	* *	192.2	333.0	0.009	653.4	*	* *
Stall Strain Fercent	0.215	0.540	1.252	1.160	0.565	* *	1.038	1,305	2.830	1.550	2.4*	* *
Half Life Hours	100	170	00#	00#	1000	2000	100	170	400	00%	1000	2000
Starting Temperature OF	1811	1811	1811	1700	1700	1700	1700	1700	1700	1589	1589	1589
Stal Tempel	2800	2800	2800	2400	2600	2600	2600	2600	2600	2400	2400	2400
Stress Level Dimensionless	• 65	٠ س	• 80	• 65	• 65	• 65	1.0	1.0	1.0	1.0	1.0	1.0
ment rature ox	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922	1922
Treatment Temperature of ok	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Heat Time Hours	4	~	~	-	-	-	-	н	H	H	-	Ħ
Heat No.	650028	650028	650028	650028	650028	650028	650028	650028	650028	650028	650028	650028
Test No.	s-130	5~133	s-137	S-140	S-151	S-153	s-110	s-111	8-109	8-145	S-152	S-154

*Pstimated **Test in Progress ***Test Not Initiated

*Extrapolated **Test In Progress

TABLE II-18. Summary of Ultra-High Vacuum Creep Test Besults on T-111 Heat 65C05C Annealed 1 Hour at 3000°F (1922°K) Plus 1 Hour 2400°F (1589°K) and Exposed for Various Times and Temperatures to Liquid Lithium or to 10-9 TORR Vacuum in G.E. Alkali Metal Exposure Program

			ı							;	•		1
Test Mo.	G.E. Specimen No.	Environ- ment	Exposure Time	e Hewpel Or be	Temperature of ok	St: KSI	Stress I MN/M2	Test Tempera	Test Temperature OF OK	1% Creep 11fe Hours	Termi cf Time, Hours	Termination cf Test me, Percent urs Creep	1% Creep Larscn-Hiller Parameter (Tog (15+logt) x1-3)
s-162	Fre-Fxpcsure	ure				35	241.0	1800	1255	528	811	4.220	40.0
S-163	Pre-Expcsure	ure				24	165.0	2000	1366	410	457	1.195	t3.3
S-164	Pre-Expcsure	ure				16	110.0	2200	1478	435	*	*	6*9#
5-121	04-37	Vacuum	1000	2400	1589	40	276.0	1650	1172	4500	4823	1.380	35.4
s-122	04-36	Vacuun	1000	2400	1589	20	344.0	1650	1172	210	1863	18.080	36.6
S-124	04-41	Vacuus	1000	2400	1589	16	110.0	2000	1366	8500#	*	* *	*9*91
s-132	04-33	Vacuum	1000	2400	1589	16	110.0	2200	1478	546	673	1.490	47.2
S-127	1-40	Lithium	1000	2400	1589	16	110.0	2200	1478	044	505	1.290	46.9
8-141	64-40	Vacuna	2000	2400	1589	20	344.0	1650	1172	340	£94	2.595	37.0
S-146	04-50	Vacuum	2000	2400	1589	35	241.0	1800	1255	745	906	1.705	40.4
S-148	04-51	Vacuum	2000	2400	1589	24	165.0	2000	1366	205	673	4.430	426
5-139	84-40	Vacuum	2009	2400	1589	97	110.0	2200	1478	885	1275	2-265	47.7
S-156	04-12	Lithium	2000	2400	1589	20	344.0	1650	1172	180	195	1.555	36.4
8-149	01-10	Lithium	2000	2400	1589	35	241.0	1800	1255	350	507	3.525	9 . 8
5-155	C4-11	Lithium	2000	2400	1589	24	165.0	2000	1366	200	692	6.550	42.6
	,												

TABLE II-16. Summary of Ultra-High Vacuum Creep Test Results on T-111 Heat 650050

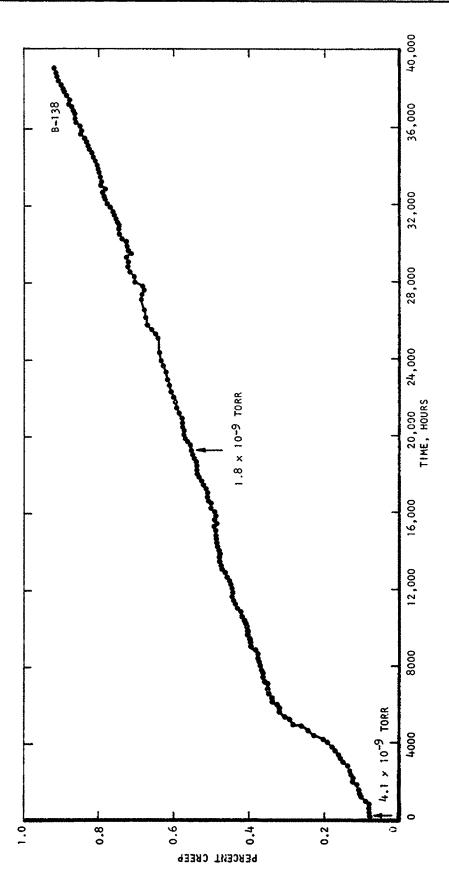
	Anne Vari	Annealed 1 Hour at 30000F (192 Various Times and Temperatures Alkali Metal Exposure Program	Summary of Ottra-Bign Vacuum Creef 19 Hour at 30000F (19220K) Plus 1 Hour 2 Hes and Temperatures to Liquid Lithium 1 Exposure Program	1000F (19 Ferature Program	19220K) res to	vacuu Plus Ligui	m creef l Hour d Lithi	rest 240001 um or	rest kesuits on 1-111 heat boudd 2400of (1589oK) and Exposed for 1m or to 10-9 ICHR Vacuum in G.E.	OK) and ICHR V	on 1-111 hear on 1-11, hear on 1-11, and Exposed TCRR Vacuum in	PSCCSC A for B G · E *	
	ta Et		Exposure	Ψ				E	1	8K :	Term	Termination	1% Creep
Test No.	Specimen No.	Environ- ment	Hime Horts	Tempe or	Tenperature of ox	Sti	Stress I MN/M2	Tempera OF	rest Temperature OP OK	Creep Life Bours	Time, Hours	lest Fercent Creep	larson-Miller Farareter (Tog (15+lugt) x1
s-157	04-13	Lithium	2005	2400	1589	16	110.0	2200	1478	1100	*	*	48.0
S-166	04-62	Vacuum	100C	1800	1255	20	344.0	1650	1172	#	8 #	19.275	33.0
s-158	04-59	Vacuum	1000	1800	1255	35	241.0	1800	1255	10	185	7.205	36.2
8-159	09-10	Vacuum	3007	1800	1255	24	165.0	2000	1366	ស	გ გ	5.400	412
S-165	04-61	Vacuum	1000	1800	1255	16	110.0	2200	1478	155	*	*	45.7
s-161	04-18	Lithium	1000	1800	1255	50	344.0	1650	1172	1/4	29	11.840	en **
5-167	04-19	Lithium	1000	1800	1255	35	241.0	1800	1255	ហ	*	* *	35.5
8-168	04-20	Lithium	1000	1800	1255	24	165.0	2000	1366	10	*	*	# *5E
s-169	04-21	Lithium	1000	1800	1255	16	110.0	2200	1478	73	*	* *	6*##

**Test In Frogress

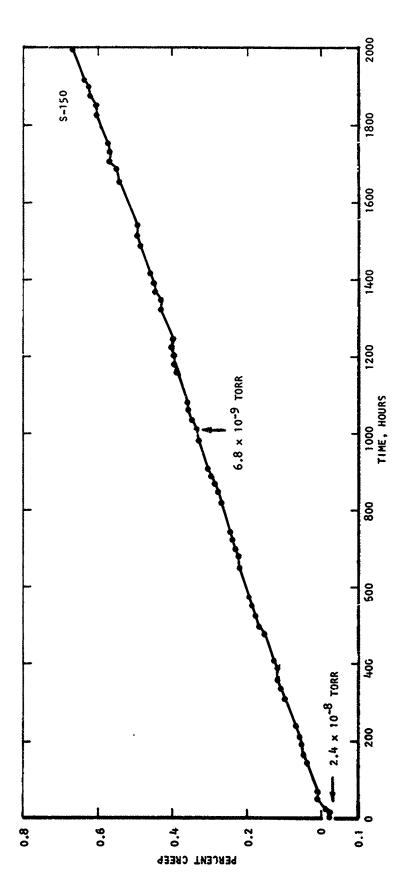
APPENDIX 1 :

CREEP CURVES

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CREEP TEST DATA, TZM HEAT NO. KDTZM-1175 STRESS RELIEVED 1 HOUR AT 2300°F (1533°K), TESTED AT 2000°F (1366°K) AND 22 KSI (151.0) MN/M²), TEST NO. B-38, TESTED IN A VACUUM ENVIRONMENT OF 1 \times 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST. FIGURE 111-1.



CREEP TEST DATA, CVD TUNGSTEN, ANNEALED 100 HOURS AT $3272^{\rm O}F$ ($2273^{\rm O}K$), TESTED AT $2912^{\rm O}F$ ($1873^{\rm O}K$) AND 2 KSI (13.8 MN/M²), TEST NO. S-150, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST. FIGURE 111-2.

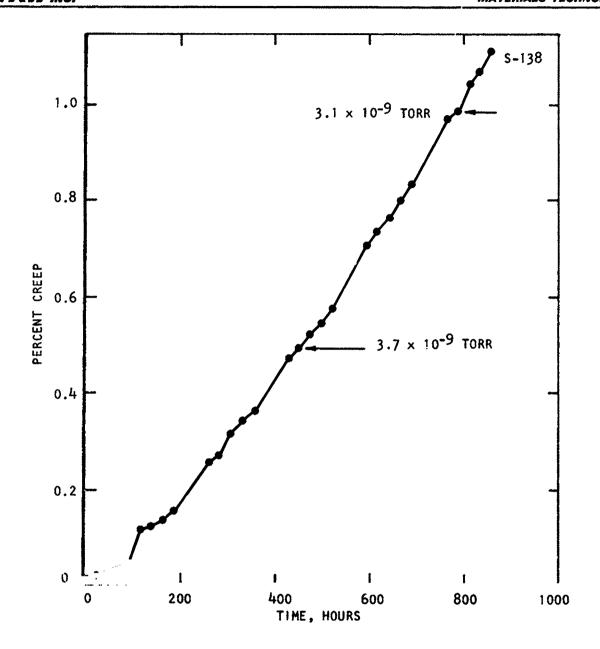


FIGURE 111-3. CREEP TEST DATA, ASTAR 811C HEAT NO. 650J56
ANNEALED 100 HOURS AT 3000°F (1922°K), TESTED AT
2400°F (1589°K) AND 15 KSI (103.0) MN/M²),
TEST NO. S-138, TESTED IN A VACUUM ENVIRONMENT OF
<1 x 10-8 TORR. ARROWS ON THE CURVES INDICATE
CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

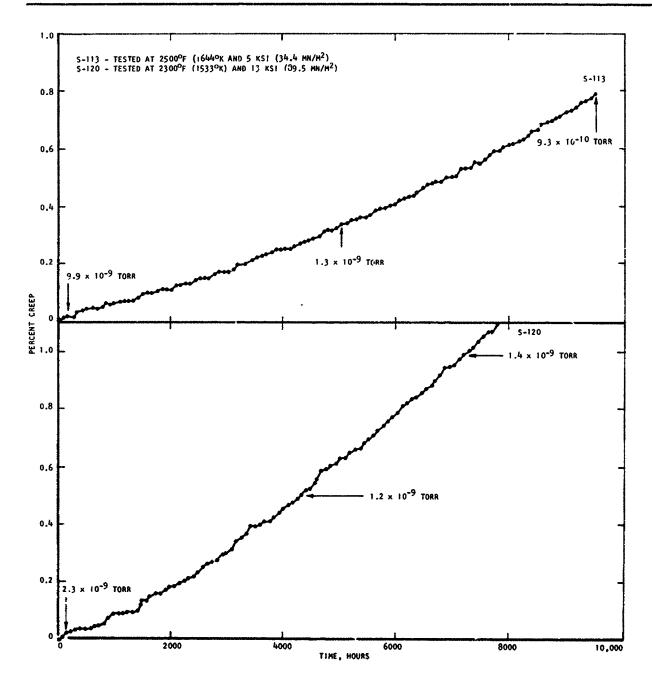
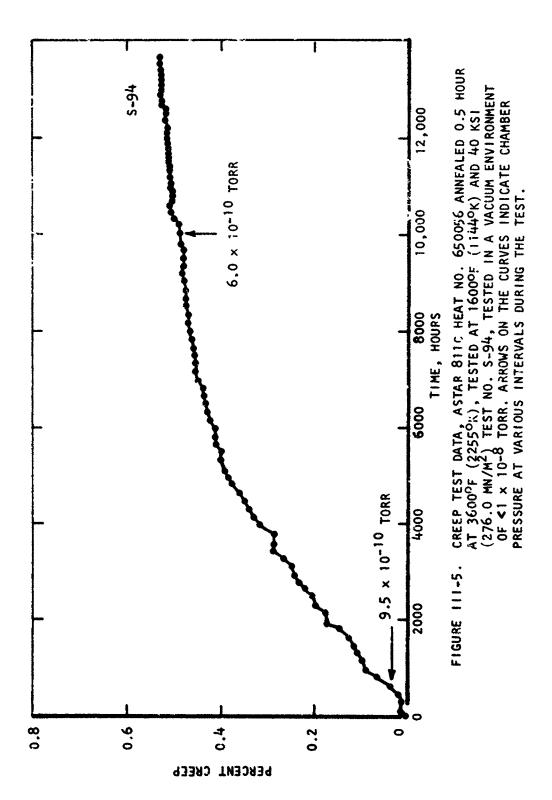


FIGURE 111-4. CREEP TEST DATA, ASTAR 811C HEAT NO. 65C056 ANNEALED 0.5 HOUR AT 3600° F (2255°K), TEST NOS. S-115 AND S-120, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

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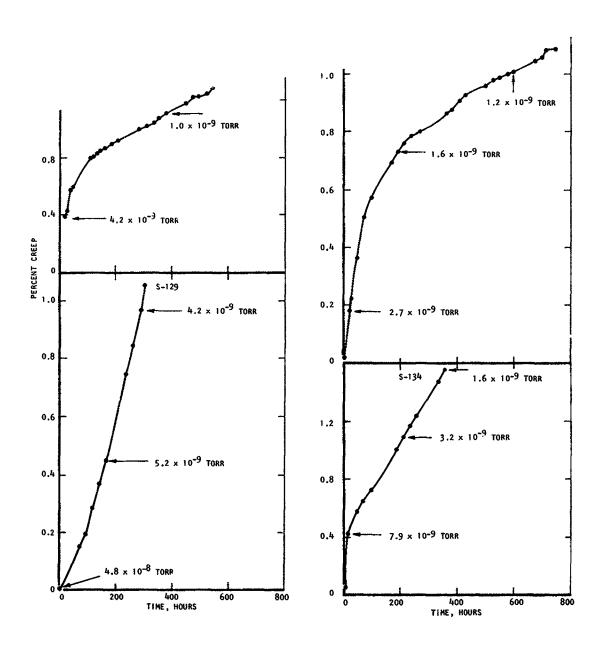
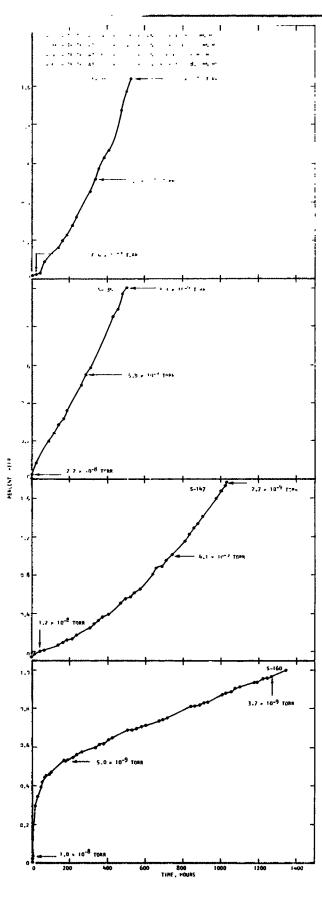


FIGURE 111-6. CREEP TEST DATA, ASTAR 811C HEAT NO. 650056 ANNEALED 1 HOUR AT 3000°F (1922°K), TEST NOS. S-128, S-129, S-131, and S-134, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10⁻⁸ TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.



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FIGURE 111-7. CREEP TEST DATA, ASTAR 811C HEAT NO. 650056 ANNEALED 1 HOUR AT 3000°F (1922°K), TEST NOS. S-135, S-136, S-147, AND S-160 TESTED IN A VACUUM ENVIRONMENT OF <1 × 10°8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

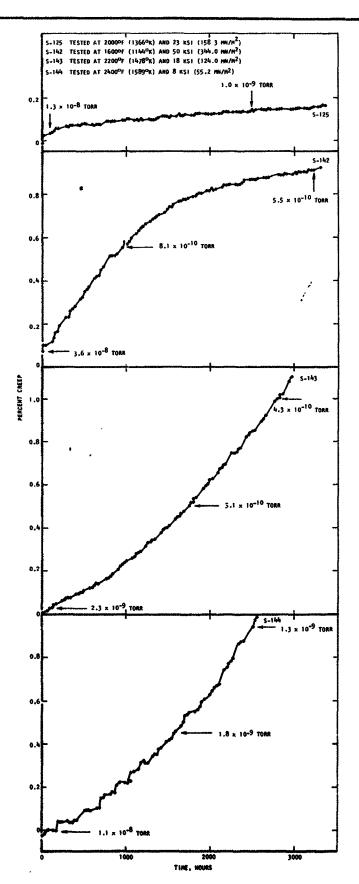


FIGURE 111-8. CREEP TEST DATA, ASTAR 811C HEAT NO. 650056 ANNEALED 1 HOUR AT 3000°F (1922°K), TEST NOS. S-125, S-142, S-143, AND S-144, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10^{-8} Torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

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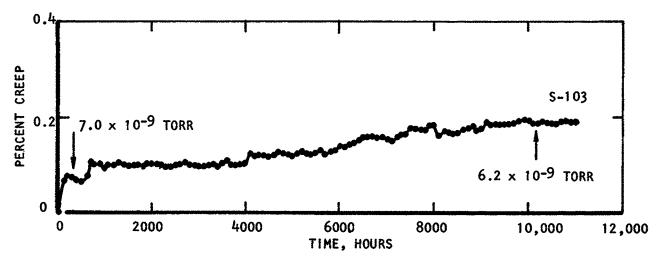
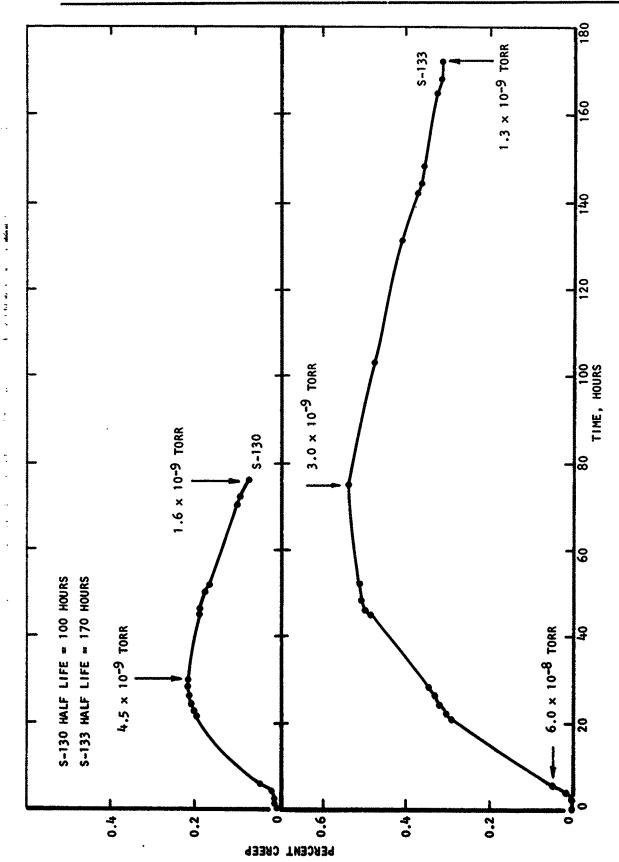


FIGURE 111-9. CREEP TEST DATA, T-111 HEAT NO. 650028 ANNEALED 1 HOUR AT 3000° F (1922°K), TESTED AT 1500°F (1089°K) AND 40 KSI (276.0 MN/M²), TEST NO. S-103, TESTED IN A VACUUM ENVIRONMENT OF 1 × 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.



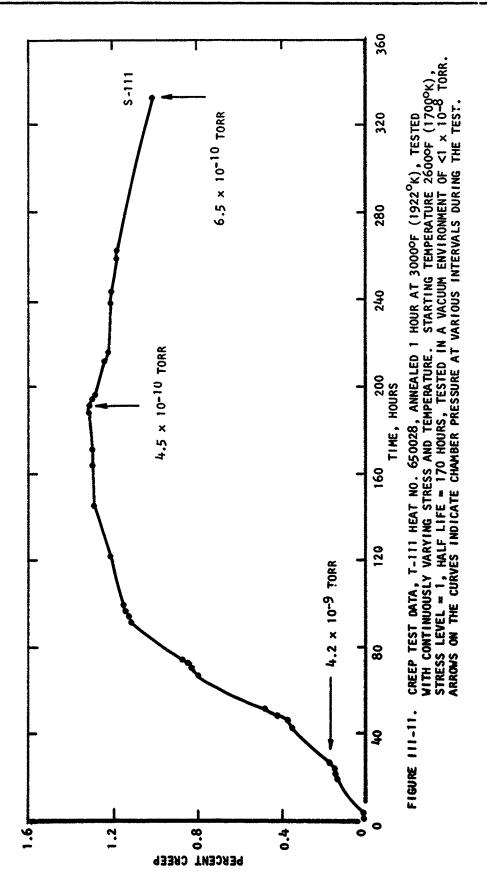
TESTED WITH CONTINUOUSLY VARYING STRESS AND TEMPERATURE. STARTING TEMPERATURE 2800°F (1811°K), STRESS LEVEL 71, TEST NOS. S-130 AND S-133, TESTED IN A VACUUM ENVIRONMENT OF <1 x 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER CREEP TEST DATA, T-111 HEAT NO. 650028 ANNEALED 1 HOUR AT 3000PF (19220K), PRESSURE AT VARIOUS INTERVALS DURING THE TEST. FIGURE 111-10.

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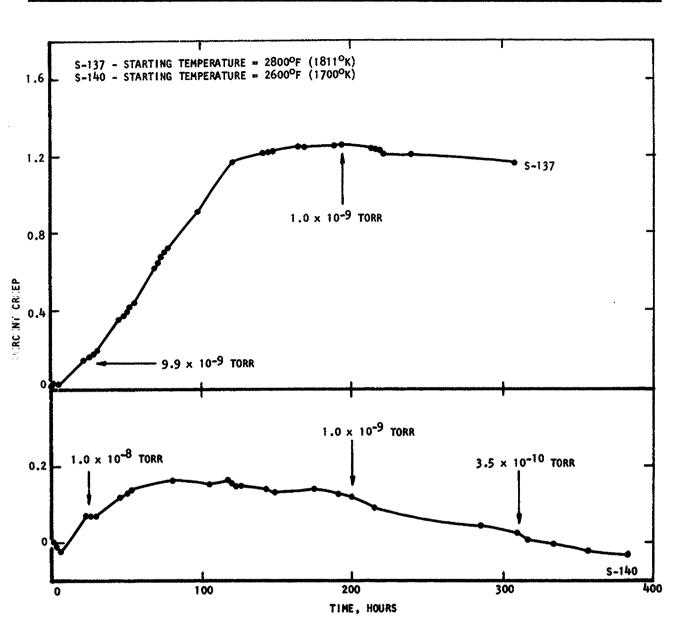
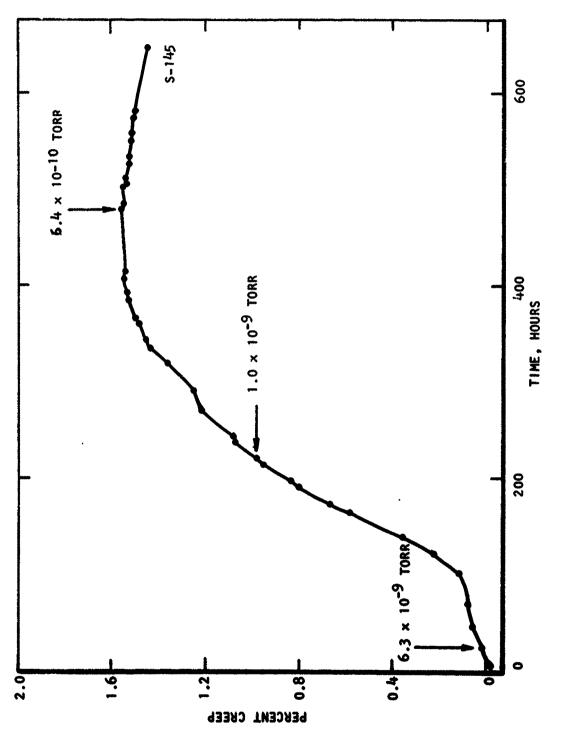


FIGURE 111-12. CREEP TEST DATA, T-111 HEAT NO. 650028 ANNEALED 1 HOUR AT 3000° F (1922°K) TESTED WITH CONTINUOUSLY VARYING STRESS AND TEMPERATURE. STRESS LEVEL 0.65, HALF LIFE 170 HOURS. TEST NOS. S-137 AND S-140, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10⁻⁸ Torr. Arrows on the curves indicate chamber PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

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CREEP TEST DATA, T-111 HEAT NO. 650028 ANNEALED 1 HOUR AT 3000°F (1922°K), TESTED WITH CONTINUOUSLY VARYING STRESS AND TEMPERATURE. STARTING TEMPERATURE 2400°F (1589°K), STRESS LEVEL 1.0, HALF LIFE 400 HOURS. TEST NOS. S-145, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST. FIGURE 111-13.

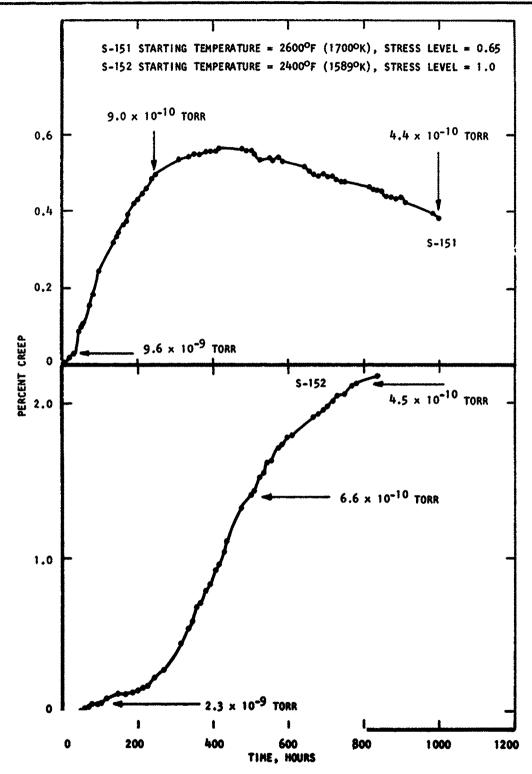


FIGURE 111-14. CREEP TEST DATA, T-111 HEAT NO. 650028 ANNEALED 1 HOUR AT 3000°F (1922°K), TESTED WITH CONTINUOUSLY VARYING STRESS AND TEMPERATURE. HALF LIFE 1000 HOURS. TEST NOS. S-151 AND S-152 TESTED IN A VACUUM ENVIRONMENT OF <1 \times 10-8 Torr. Arrows on the curves indicate chamber Pressure at various intervals during the test.

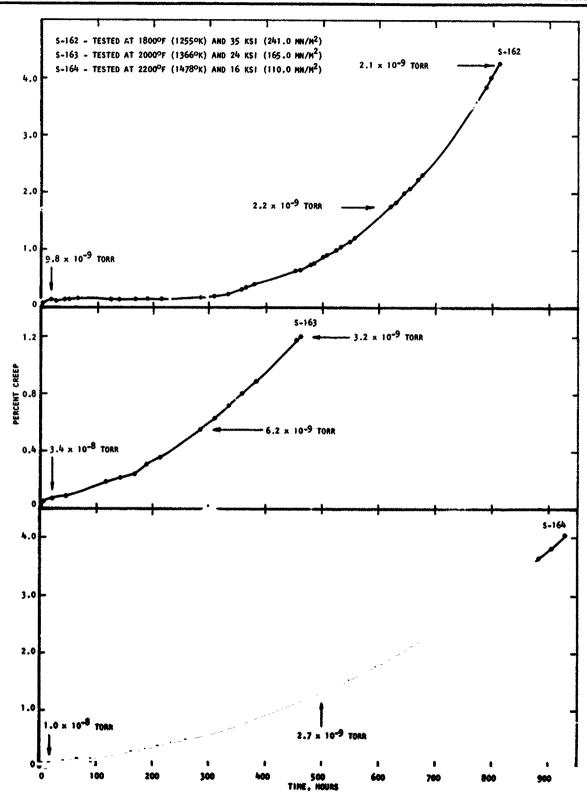


FIGURE 111-15. CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K), REPRESENTING THE PRE-EXPOSED CONDITION FROM THE G.E. ALKALI METAL EXPOSURE PROGRAM. TEST NOS. S-162, S-163, AND S-164, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

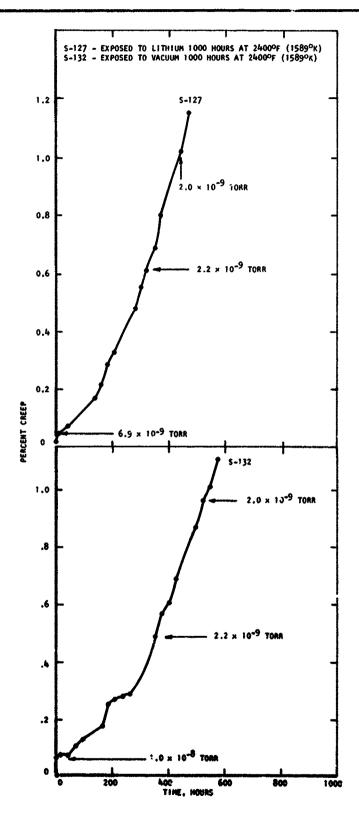
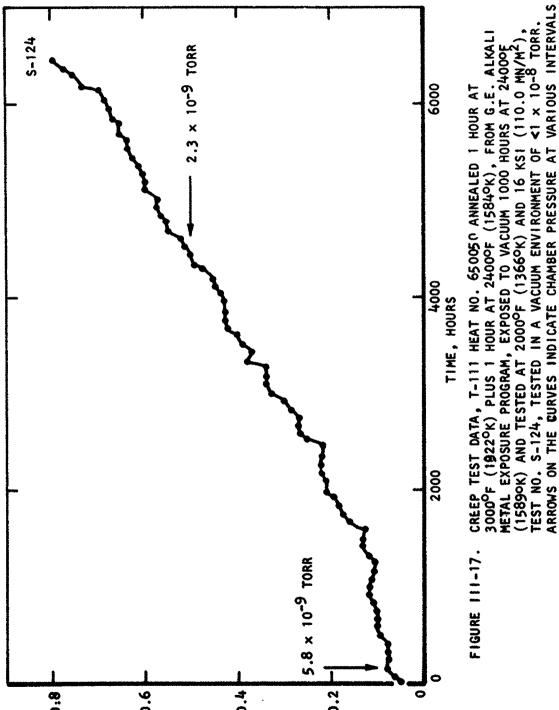


FIGURE III-16. CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K), FROM G.E. ALKALI HETAL EXPOSURE PROGRAM, TESTED AT 2200°F (1478°K) AND 16 KSI (110.0 MN/M²), TESTED IN A VACUUM ENVIRONMENT OF <1 x 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

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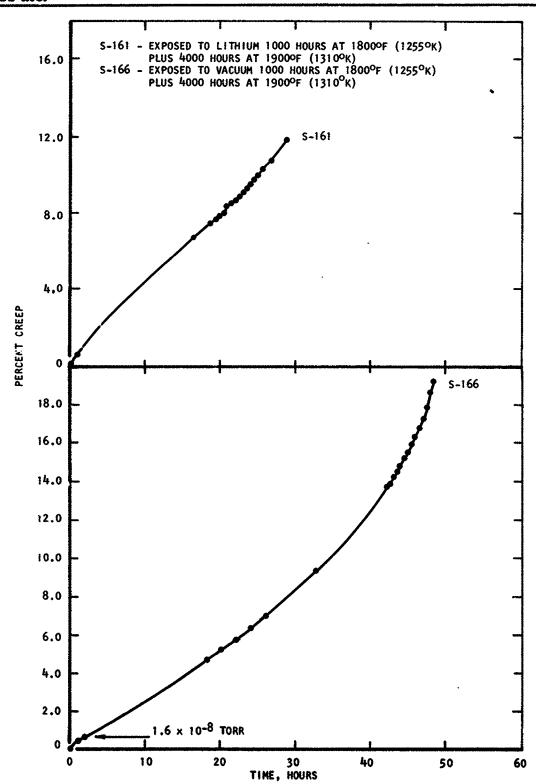


FIGURE 111-18. CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K), FROM G.E. ALKALI METAL EXPOSURE PROGRAM, TESTED AT 1650°F (1172°K) AND 50 KSI (344.0 MN/M²), TEST NOS. S-161 AND S-166, TESTED IN A VACUUM ENVIRONMENT OF <1 x 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

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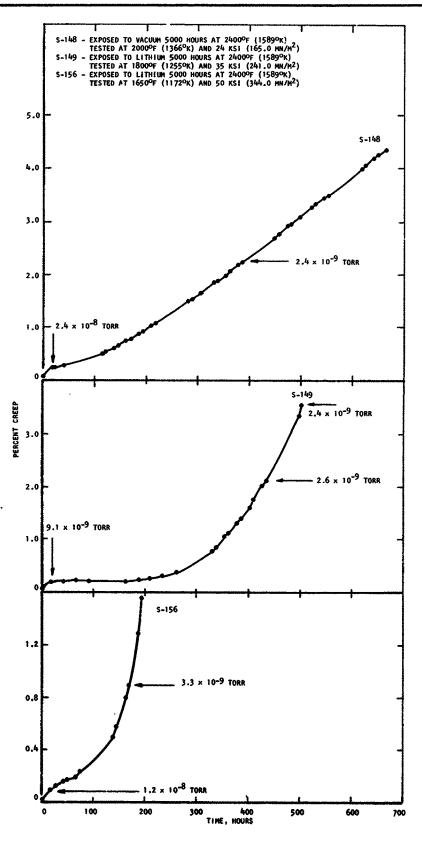


FIGURE 111-19. CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K), FROM G.E. ALKALI METAL EXPOSURE PROGRAM, TEST NOS. S-148, S-149, AND S-156, TESTED IN A VACUUM ENVIRONMENT OF <1 × 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

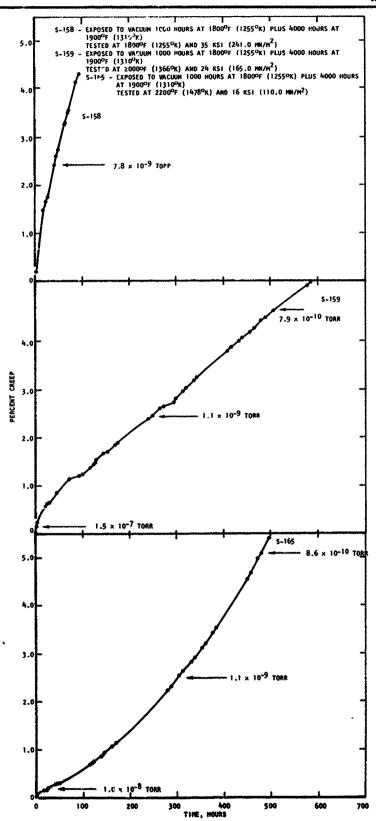


FIGURE 111-20. CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K), FROM G.E. ALKALI METAL EXPOSURE PROGRAM. TEST NOS. S-158, S-159, AND S-165, TESTED IN A VACUUM ENVIRONMENT OF <1 x 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

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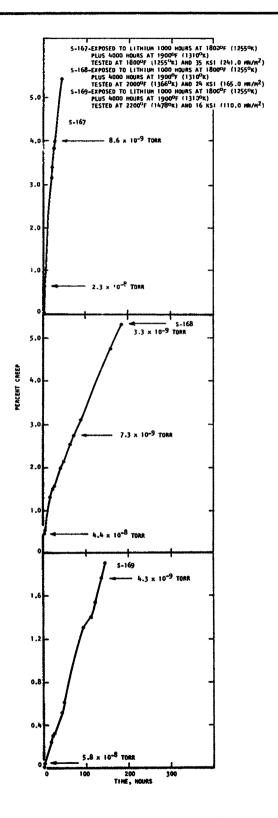


FIGURE 111-21. CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K), FROM G.E. ALKALI METAL EXPOSURE PROGRAM. TEST NOS. S-167, S-168, AND S-169, TESTED IN A VACUUM ENVIRONMENT OF <1 x 10-8 TORR. ARROWS ON THE CURVES INDICATE CHAMBER PRESSURE AT VARIOUS INTERVALS DURING THE TEST.

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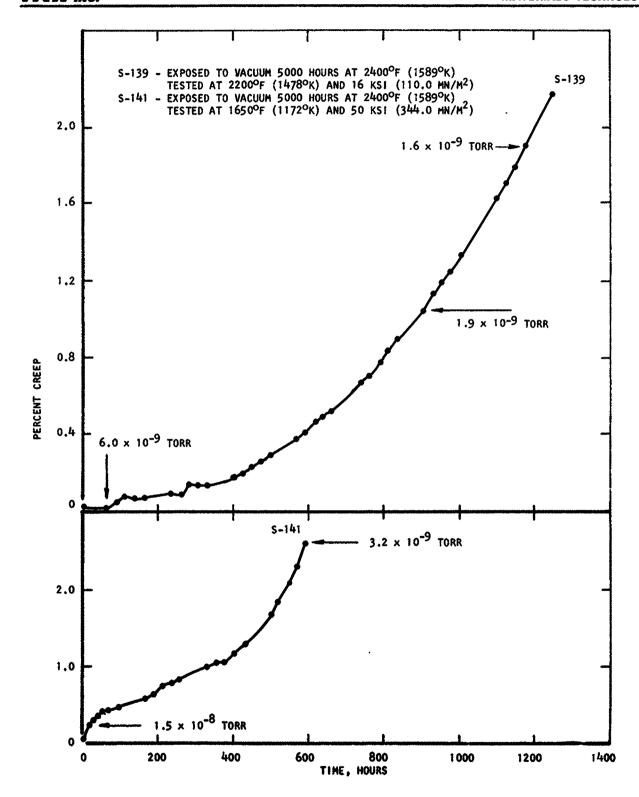
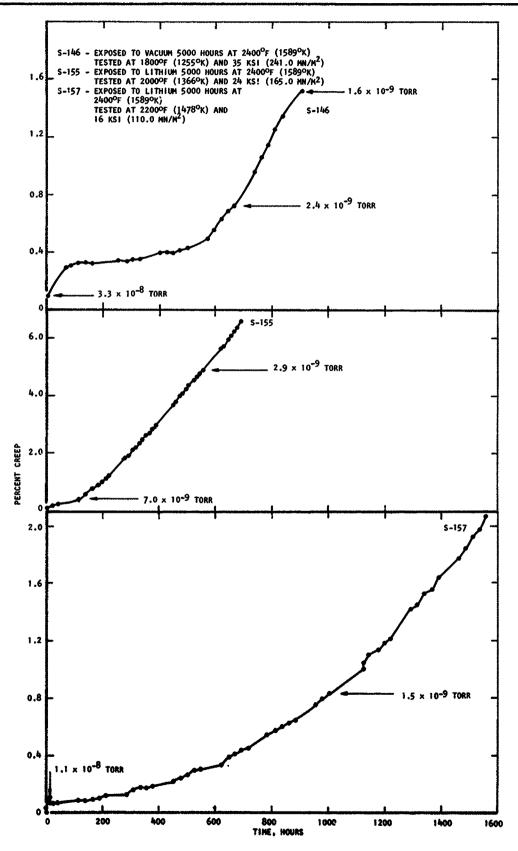


FIGURE 111-22. CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) PLUS 1 HOUR AT 2400°F (1589°K), FROM G.E. ALKALI METAL EXPOSURE PROGRAM. TEST NOS. S-139 AND S-141, TESTED IN A VACUUM ENVIRONMENT OF <1 \times 10-8 Torr. Arrows on the curves indicate Chamber pressure at various intervals during the test.



CREEP TEST DATA, T-111 HEAT NO. 650050 ANNEALED 1 HOUR AT 3000°F (1922°K) FIGURE 111-23. PLUS 1 HOUR AT 2400°F (1589°K), FROM G.E. ALKALI METAL EXPOSURE PROGRAM. TEST NOS, S-146, S-155, AND S-157, TESTED IN A VACUUM ENVIRONMENT OF $<1\times10^{-8}$ Torr. Arrows on the curves indicate chamber pressure at VARIOUS INTERVALS DURING THE TEST.